DEPARTMENT OF THE NAVY
NAVAL RESEARCH LABORATORY
WASHINGTON, D.C. 20375

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IN REPLY REFER TO:
3900
Ser 6310-25N

AUG 13 1986

Department of the Interior
Minerals Management Service
Attn: Mr. John B. Gregory (MMS-Mail Stop 647)
Reston, VA 22091

Re: LOAD INTERACTION EFFECTS ON ENVIRONMENTAL CRACKING OF HIGH-STRENGTH TENSIONED MEMBERS

Gentlemen:

Enclosed please find a Progress Report on An Investigation of Stress-Corrosion Cracking Susceptibility of Candidate Steels for Tension-Leg Platform Tendons, enclosure (1). If additional information is required, please contact Mr. T. W. Crooker, Code 6310, Material Science and Technology Division, (202) 767-6380.

Sincerely,

R. J. Goode

R. J. GOODE
Acting Superintendent, Material Science and Technology Division
By direction of the Commanding Officer

Encl:
(1) Cited

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Acting Superintendent, Material Science
and Technology Division
By direction of the Commanding Officer

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8/18/86

LETTER REPORT

Progress Report on An Investigation of Stress-Corrosion Cracking Susceptibility in Candidate Steels for Tension-Leg Platform Tendons

J. A. Hauser II and T. W. Crooker
Environmental Effects Branch
Material Science and Technology Division
Code 6310
Naval Research Laboratory
Washington, DC 20375-5000

Background: A previous report described stress-corrosion cracking (SCC) tests conducted on two candidate tension-leg platform (TLP) tendon steels supplied to the Naval Research Laboratory (NRL) by Conoco Inc. [1]. These two steels were among a group of 11 steels, including various compositions, strength levels and product forms, tested for SCC susceptibility in natural seawater at NRL's Marine Corrosion Research Laboratory in Key West, Florida using fracture mechanics test methods.

No evidence of SCC susceptibilty was found among any of the materials included in that study. However, further SCC testing has been conducted on one of the Conoco steels at NRL in Washington for the following reasons. First, previous experience suggested that steels of the strength level of this Conoco steel (yield strength = 120 ksi) are likely to exhibit some degree of SCC susceptibility in seawater when cathodically polarized to -1,000 mV vs. Ag./AgCl. Second, a subsequent Navy study on the influence of experimental variables on SCC testing indicated that the combination of factors chosen for the initial study (i.e., the bolt-loaded WOL specimen, natural seawater and zinc anodes) have a remarkably pronounced effect on suppressing SCC sensitivity in steels of the strength level studied [2].

Progress: Each of the two Conoco steels were initially tested using a pair of 2-T WOL test specimens. Following the initial tests at NRL-Key West, sufficient material remained in each WOL specimen to permit fabricating a 2 x 2-inch cross-section cantilever-beam specimen. The cantilever-beam configuration was chosen because, following the conclusion of the Navy study on test method variables, it was apparent that the most severe and least ambiguous conditions for measuring the fracture mechanics SCC threshold parameter (K_{Iscc}) consisted of the deadweight-loaded cantilever-beam specimen immersed in 3.5% NaCl solution using a potentiostat device to control the cathodic potential. These were the conditons chosen for this follow-on test.

Encl (1)

In the Navy program, which included a 5Ni-Cr-Mo-V steel with a yield strength of 140 ksi, it was found that numerous bolt-loaded WOL specimens failed to initiate SCC despite having initial crack-tip stress-intensity (K_I) levels well in excess of K_{ISCC}. This is thought to be a caused by a relaxation effect inherent in the bolt-loading method. Also, in tests using the cantilever-beam specimen on the same steel, results indicated that the combination of 3.5% NaCl solution and a potentiostat device produced the most conservative and least ambiguous measurement of K_{ISCC}, as illustrated in Figure 1. It is not entirely clear why the use of natural seawater and/or zinc anodes has such a pronounced effect on K_{ISCC} measurement, but the most likely explaination at the present time is that either of these factors tends to produce corrosion products which may plug the crack and inhibit access of the environment to the crack tip.

A cantilever-beam specimen of Conoco steel "B" has been tested. The results of this test are shown in Figure 2. It was initially loaded to a K_I level of 96 ksi$\sqrt{}$in. for 2,000 hours without indication of crack growth. Testing was then interrupted to extend the fatigue precrack and it was reloaded to a K_I level of 120 ksi$\sqrt{}$in. for 4,500 hours, again without indication of crack growth. At that point, a 3% ripple-load was added while maintaining the maximum stress-intensity level (K_{max}) at 120 ksi$\sqrt{}$in. Ripple-loading has been found to increase the susceptibility to SCC in steels [3]. The specimen failed by fracture after 3,000 hours of ripple-loading ($\approx$ 1,000,000 cycles) at a frequency of 0.1 Hz..

It is difficult to draw broad conclusions from a single test. It is likely that a steel of this strength level will be susceptible to SCC if loaded at a sufficiently high K_I level for a sufficiently long period of time. It is possible to speculate that the ripple-loading was a causitive factor in the SCC failure process. Additional tests on candidate high-strength steels for TLP structures are planned to help resolve the role of ripple-loading in long-term SCC phenomena.

References

[1] J. A. Hauser II and T. W. Crooker, "An Investigation of Stress-Corrosion Cracking Susceptibility in Candidate Steels for Tension Leg Platform Tendons," NRL Memorandum Report 5773, April 24, 1986.

[2] R. W. Judy, Jr., J. A. Hauser II and T. W. Crooker, "Influence of Experimental Variables on the Measurement of Stress-Corrosion Cracking Properties of High-Strength Steels," NRL Memorandum Report (pending).

[3] T. W. Crooker and J. A. Hauser II, "A Literature Review on the Influence of Small-Ampitude Cyclic Loading on Stress-Corrosion Cracking in Alloys," NRL Memorandum Report 5763, April 3, 1986.

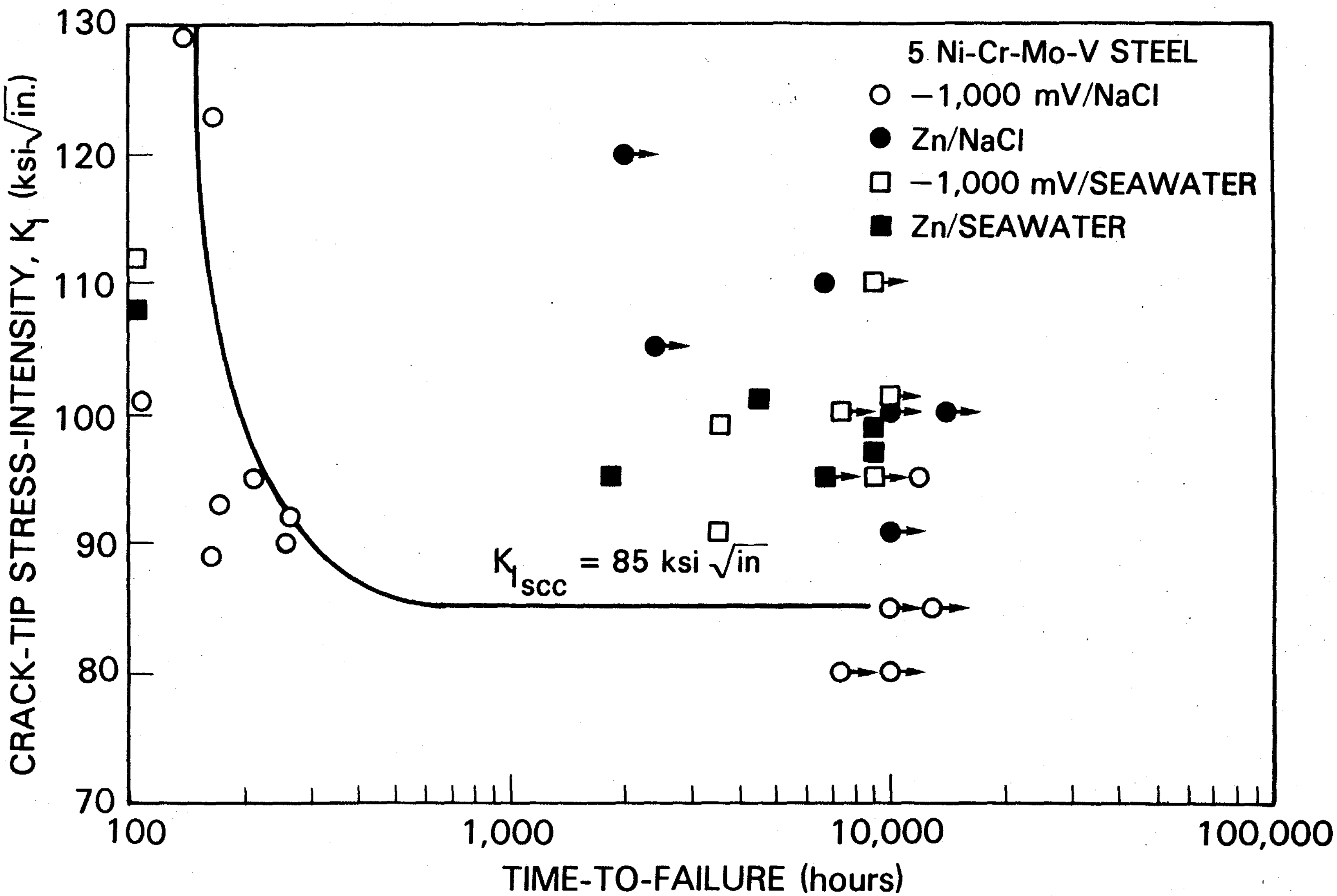

Figure 1 - Stress-intensity (K_I) vs. time-to-failure data for 5Ni-Cr-Mo-V steel using precracked cantilever-beam specimens. Note that the lowest apparent K_{Iscc} value (85ksi$\sqrt{}$in.) is obtained using 3.5% NaCl solution and a potentiostat device.

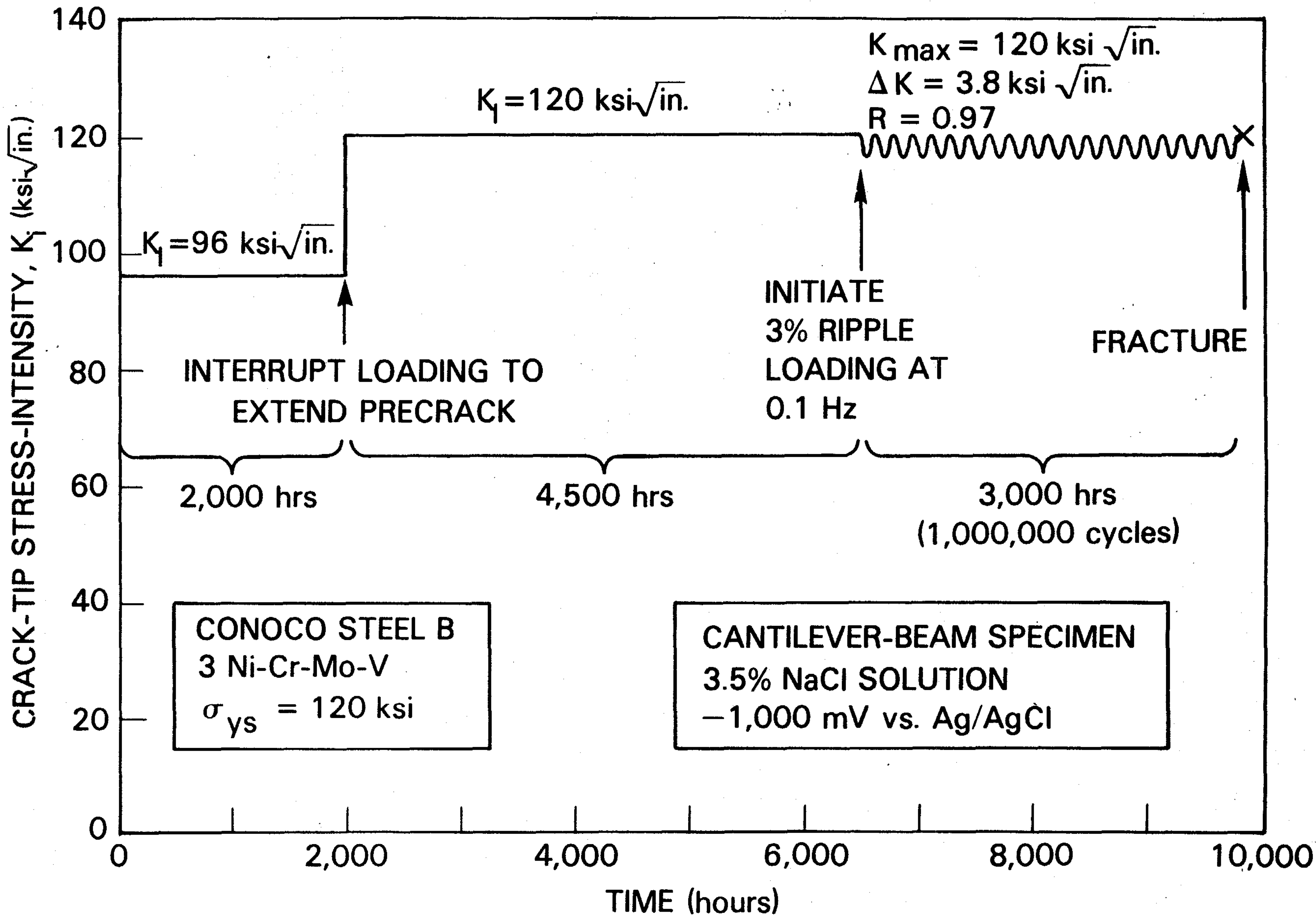

Figure 2 - K_I vs. time-to-failure history for a precracked cantilever-beam specimen of Conoco steel B tested in 3.5% NaCl solution at -1,000 mV using a potentiostat under static loading and under 3% ripple-loading.